Blended and Integrated Teaching of Theory, Simulation and Practice of Measurement and Control Circuit Course

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Abstract. To bridge the gap between theory teaching, simulation teaching and practice teaching of measurement and control circuit course, the knowledge system of "signal and system theory, circuit principle and circuit practice" was constructed, and the teaching concept of dialectical unity of theory, simulation and practice based on blended and integrated teaching was put forward. By using simulation software, Analog Discovery Studio (ADS) portable virtual instrument, and the technique of displaying multiple user screens on the same screen, the TGSPUT teaching mode based on mixing and integrating of theory, simulation and practice was build. In this paper, the design and implementation of TGSPUT teaching mode is introduced in detail by taking the analysis of virtual short characteristics of operational amplifier as an example. The proposed teaching method well integrates theoretical teaching, simulation teaching and practical teaching, so that the students can be changed from "high score but low capability" to "high score and high capability". It provides an effective way for cultivating high-level practical talents.

Keywords: blended and integrated teaching · virtual short · measurement and control circuit · simulation software · portable virtual instrument

1 Introduction

Engineering courses emphasize both theoretical teaching and practical teaching. Because of the conflict and disconnection between practical teaching and theoretical teaching in time, content, teachers and so on, the teaching effect of the course is affected. How to realize the integration of practical teaching and theoretical teaching and give full play to the role of practical teaching is the difficulty and focus of course teaching. Liu Meiling, et al. [1] noticed the disconnection between theory and practice teaching of remote sensing geoscience application course for geographic information science major and the lack of students' ability to solve practical problems by applying theoretical knowledge, and thus put forward a teaching mode of combining theoretical teaching of "online learning + classroom face-to-face teaching" with practical teaching of "problem inquiry + flipped

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classroom". Han Jian [2] changed the traditional teaching mode of Network Engineering Drawing into a "three-step" teaching mode of preview before class, classroom flipping and supplement after class, and classroom flipping is implemented in three parts: theoretical study first, then simulation experiment, and finally practice in the real environment, thus realizing "student-centered" teaching and learning and greatly improving students' interest in learning and intellectual curiosity. Shu Jun et al. [3] conducted teaching design based on the characteristics of each knowledge point in the teaching content of Sampling Theorem, integrated diversified teaching means such as dynamic graphic demonstration, audio files, MATLAB simulation and experiment boxes, and various teaching methods such as lecture method, heuristic method, deduction method and case study to strengthen the integration of theory and practice. Deng Li et al. [4] used the new blended teaching mode of pump-probe virtual simulation experiment assisting theoretical course, to help students master the basic probe principle of pump-probe and cultivate students' experimental operation skills. Ye Yan, et al. [5] taking the spectrometer experiment in general physics as an example, explored and practiced the blended professional experimental teaching mode of "theoretical teaching + online video and platform simulation + offline experiment", which broke through the limitation of experimental time and space, aroused students' enthusiasm for autonomous learning, and improved students' experimental skills, comprehensive quality and creativity. Wang Yuqing et al. [6] put forward a blended teaching mode of theoretical teaching and experimental teaching based on OptiSystem simulation design for the course of Optical Fiber Communication, which was helpful for students to understand and master the knowledge in all dimensions and from multiple angles, and cultivate their creativity and engineering practical ability.

The course of measurement and control circuit is the core professional course of measurement and control technology and instrument major, which includes two parts: theoretical teaching and experimental teaching. In view of the disconnection between theoretical teaching and practical teaching of measurement and control circuit course, a blended integrated teaching platform of measurement and control circuit theory, simulation and practice was constructed, and the blended integrated teaching mode of theory, simulation and practice was practiced and explored.

2 Design Concept of Blended and Integrated Teaching of Theory, Simulation and Practice of Measurement and Control Circuit Course

Blended learning includes macro and micro levels, which is a mixture of various learning methods, media techniques, learning contents, learning models, student support services and learning environments. However, blended learning is not a simple blending of these elements, but an in-depth integration of them, giving full play to teachers'guidance, inspiration and leading role in the teaching process, and reflecting students'initiative, exploration and creativity as learning subjects. Integrated teaching intends to break the traditional subject system and teaching model, and to integrate theoretical teaching, simulation teaching and practical teaching from the aspects of courses, teaching plans and classrooms. The blended integrated teaching method of measurement and control circuit course is designed in detail based on the following teaching concepts, which lays a foundation for the development of blended integrated teaching.

2.1 Construct the Knowledge System of Measurement and Control Circuit Course "Integration of Signal and System Theory, Basic Theory of Control Engineering-Circuit Principle-Circuit Practice"

To realize the educational objective of high-level practical talents in measurement and control major, the curriculum framework of measurement and control circuit with equal emphasis on theoretical teaching and practical teaching is constructed as shown in Fig. 1. The theoretical knowledge of measurement and control circuits includes 'the principle of measurement and control circuit' and its interdependent 'signal and system theory', 'basic theory of control engineering'. 'The principle of measurement and control circuit' is the information carrier of 'signal and system theory', and 'basic theory of control engineering'. The analysis methods of 'signal and system theory', and 'basic theory of control engineering' in the time domain, frequency domain and complex frequency domain are effective means to analyze 'the principle of measurement and control circuit'. In the teaching of measurement and control circuit theory, the inner connection and unity between the principle of measurement and control circuit and the basic knowledge of signal and system, and control engineering are emphasized, which exposing the essence of the circuit. The theoretical knowledge of measurement and control circuits plays a guiding role in the practice of measurement and control circuits. Practical teaching can not only verify the theoretical knowledge, but also further develop and improve the theoretical knowledge.

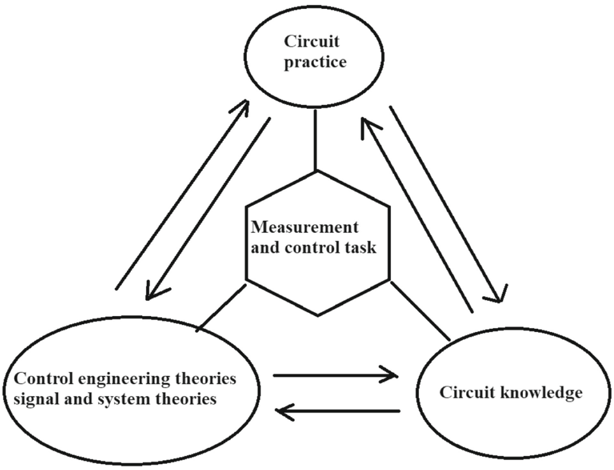

Fig. 1. Knowledge system of measurement and control circuit course

2.2 Blended and Integrated Teaching Concept of Theory, Simulation and Practice of Measurement and Control Circuit

In addition to the theoretical teaching and practical teaching, Matlab, Multisim and other software can be used to simulate the principle or circuit of measurement and control circuit. Generally speaking, theoretical courses, simulation courses and practical courses are taught by different teachers at different times and places, using different teaching materials or instruction books, and different assessment standards, which leads to the disconnection among theoretical teaching, simulation teaching and practical teaching of the circuit courses. Therefore, the idea and method of blended integration of measurement and control circuit theory-simulation-practice are put forward, which means the course can be taught by the same or the same group of teachers at the same time, in the same classroom, using the same teaching material or instruction book. Students can firmly grasp the basic theoretical knowledge of measurement and control circuit through online learning and offline learning, deepen the understanding of theoretical knowledge through simulation (Matlab and Multisim) verification, more importantly, explore the unknowns, deepen the understanding of theoretical knowledge through practical verification, master the similarities and differences between theory, simulation and practice, and realize the dialectical unity of measurement and control circuit theory, simulation and practice and the sublimation of measurement and control circuit knowledge. The blended integrated teaching method of measurement and control circuit courses blurs the boundary among theoretical, simulation and practical teaching, and well integrates theoretical, simulation and practical teaching, so that the students can be changed from "high score but low capability" to "high score and high capability". It improves the students' engineering practical ability and comprehensive quality of scientific research, and provides an effective way for cultivating high-level practical talents.

3 Blended and Integrated Teaching Mode of Theory, Simulation and Practice of Measurement and Control Circuit Course

Blended and integrated teaching of theory, simulation and practice of measurement and control circuit can be conducted in both labs and classrooms. The following equipment or technologies are required. (1) Matlab and Multisim simulation software; (2) Portable circuit instrument: DIGILENT Analog Discovery Studio (ADS); (3) Measurement and control circuit unit brassboard:The unit circuit in each chapter of Measurement and Control Circuit is made into a brassboard. The key chips, resistors and capacitors on the brassboard are pin-type, which can be replaced and is convenient for circuit characteristic analysis and debugging. (4) Multi-user on screen display software: teachers can display the simulation results and experimental results of each student at any time on the large screen of the classroom, which is convenient for discussion between teachers and students, and between students and students.

TGSPUT teaching mode based on blended and integrated teaching of theory, simulation and practice of measurement and control circuit course is shown in Fig. 2. The cycle "Theory → Guidance → Simulation → Practice → Unification → Theory" starts from theory and finally comes back to theory. (1) Theory: it mainly introduces the basic

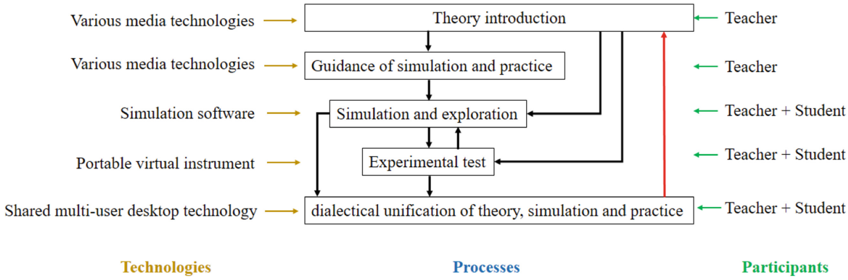

Fig. 2. Blended and integrated teaching mode of measurement and control circuit course

theoretical knowledge of measurement and control circuit. (2) Guidance: the teacher guides the research contents of Simulation and Practice according to the key points and difficult points of the basic theoretical knowledge. (3) Simulation: the circuit theory is verified by simulation software such as Matlab and Multisim, and the understanding of basic theoretical knowledge is deepened. More importantly, some unknown content is explored. (4) Practice: the portable instrument ADS of DIGILENT Company, and the unit brassboard or unit circuit built by breadboards are used for debugging, measurement and analysis in the experiment. The circuit theory is verified through the practical process, the understanding of basic theoretical knowledge is deepened, and more important and unknown experimental phenomena are explored. The research contents of the Practice period can be modified according to the results of the Simulation period, and the results of the Practice period, in turn, form the demand for re-simulation of some contents. (5): Unification: the similarities and differences of basic theory, simulation results and experimental results are compared and analyzed, and the causes for the inconsistency between theory and simulation, theory and practice, simulation and practice are explored with a reasonable explanation. There must be a deviation between the actual circuit and the ideal circuit. However, as long as the deviation is within the specifications of the measurement and control system and can meet the needs of the system, it can be considered that the practical results are consistent with the circuit theory, realizing the dialectical unity of the measurement and control circuit theory, simulation and practice, further perfecting the basic theory of the measurement and control circuit or proposing new theories, and achieving the sublimation of the knowledge of the measurement and control circuit.

4 Examples of Blended and Integrated Teaching: Operational Amplifier Virtual Short Characteristics

4.1 Theory Introduction of Operational Amplifier Virtual Short Characteristic

When the operational amplifier circuit is working, if there is zero difference between the operational amplifier's two input voltages, it is considered that there is virtual short in the operational amplifier. The reason why there is virtual short in the operational amplifier is that the operational amplifier circuit has introduced strong negative feedback, that is, the loop circuit amplification $|AF| > > 1$.

4.2 Guidance on Simulation and Practice

Before simulation and experiment, teachers guide students through the methods, contents and key directions of simulation and experiment, so that students can use their imagination and creativity, discover problems and inconsistent findings in simulation and experiment, and lay a foundation for perfecting the judgment theory of virtual short characteristics.

4.3 Simulation and Practice Results of Virtual Short Characteristic of Noninverting Amplifier

Simulation and practice results of virtual short characteristic of noninverting amplifier is shown in Fig. 3.

4.4 Dialectical Unification of Theory, Simulation and Practice

Question 1: As shown in the simulation results of Fig. 3 (c) and the experimental results of Fig. 3 (e), when the frequency of input signal is low, there is no difference between voltages of noninverting and inverting input, and there is virtual short phenomenon. The closed-loop gain of simulation and experiment are equal to the theoretical values. As shown in the simulation results of Fig. 3 (d) and the experimental results of Fig. 3 (f), when the frequency of input signal is the cut-off frequency, there is a difference between voltages of noninverting and inverting input, without virtual short phenomenon. The closed-loop gain of simulation and experiment are not equal to the theoretical values.

Question 2: As shown in the experimental results of Fig. 3(g), when the feedback resistance R2 = 10k, there is no difference between voltages of noninverting and inverting input, and there is virtual short. As shown in the experimental results of Fig. 3 (h), when the feedback resistance R2 = 910k, there is difference between voltages of noninverting and inverting input, without virtual short.

Theoretical analysis: The formula of voltage difference between noninverting and inverting input of noninverting amplifier and close-loop gain errror are shown as Eq. (1) and (2):

$$\Delta u = u_+ - u_- = \frac{u_i}{1 + A\frac{R_1}{R_1+R_2}} \tag{1}$$

$$\Delta A_f = \frac{A}{1+AF} - \frac{1}{F} = \frac{-1}{(1+AF)F} = \frac{A}{1+A\frac{R1}{R1+R2}} - \frac{R1+R2}{R1}. \tag{2}$$

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When the frequency of input signal is high, the open-loop voltage gain A of the amplifier decreases, and the feedback coefficient F of the noninverting amplifier decline when the feedback resistor R2 goes up. Both cases will cause the strong negative feedback condition of |AF|> > 1 to be reduced, with Δu increased.

Reminder: The increase of the amplifier's closed-loop gain will lead to reduced negative feedback depth and decreased amplifier gain accuracy. Therefore, the single-stage amplifier's amplification cannot be too large!

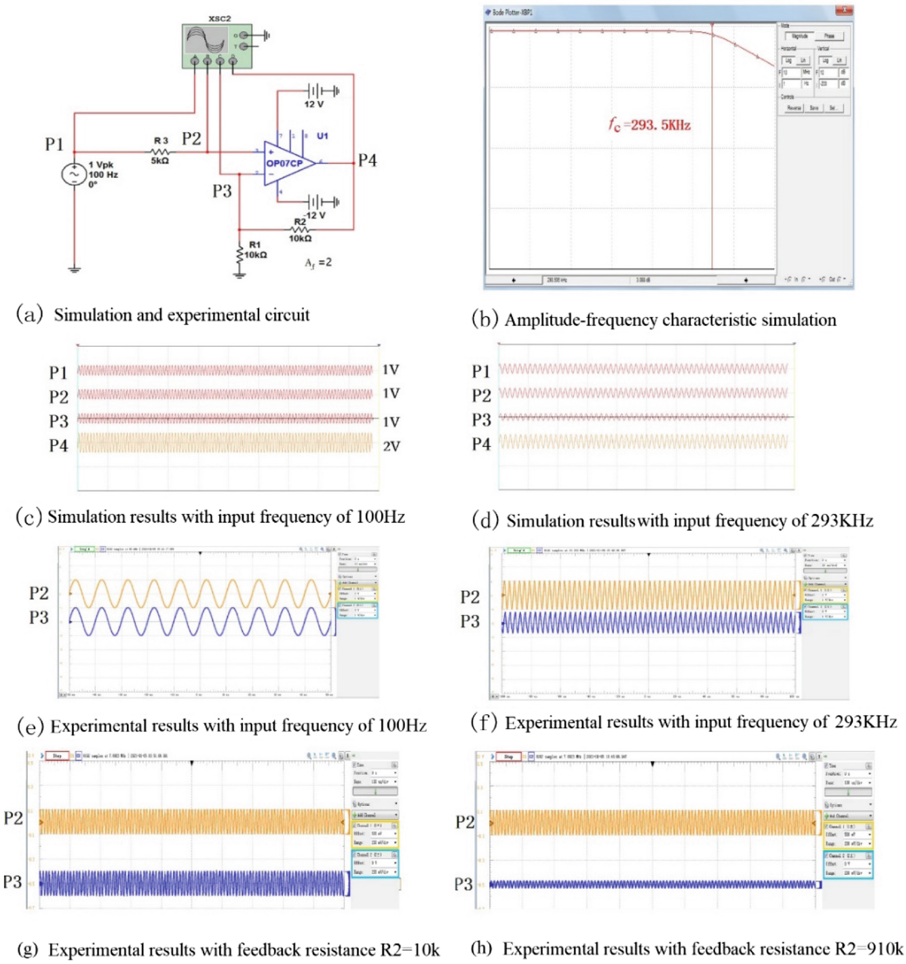

Fig. 3. Simulation and practice results of virtual short characteristic of noninverting amplifier

4.5 Circuit Status Analysis of Operational Amplifier Based on Virtual Short Phenomenon

If there is no negative feedback in the operational amplifier circuit, there must be no virtual short, thus it can be judged that the circuit works in a nonlinear state, such as zero-crossing comparator and hysteresis comparator with positive feedback.

If there is only DC negative feedback and virtual short in operational amplifier circuit, it can be judged that the circuit works in linear amplification state.

If there is only DC negative feedback in the operational amplifier circuit, when the strong negative feedback condition $|AF| > > 1$ is not satisfied, although the noninverting and inverting input voltages are no longer exactly the same, the frequency of the output signal is the same as that of the input signal. In this case, it is necessary to consider whether the accuracy of the operational amplification circuit meets the engineering requirements.

If there is only AC negative feedback such as the integrating circuit, when the frequency is very low, the strong negative feedback condition is not satisfied, and there is no virtual short.

If there are both negative feedback and positive feedback in the operational amplifier circuit when the positive feedback is weak, there is a virtual short phenomenon, and the functions of the linear system can be realized. When the positive feedback is strong, there is an oscillation in the circuit and the functions of the linear system cannot be realized. There are both negative feedback and positive feedback in signal generator circuits (such as square wave generators, and triangular wave generators). Under the joint action of positive feedback and negative feedback, there is an oscillation in the circuit, which produces the required oscillation wave and realizes the function of the nonlinear system.

5 Conclusions

Circuit, signal and system, theory, simulation and practice are the elements that are supportive and integrated into the course of measurement and control circuit. With the help of such technologies as simulation software, portable circuit instrument, unit breadboard of measurement and control circuit, and multi-user on-screen display, the teaching idea of unification of theory-simulation-practice is implemented, and the TGSPUT teaching model of Theory → Guidance → Simulation → Practice → Unification → Perfection of theory is explored and verified. Through theoretical analysis, circuit simulation and practice of typical operational amplifier circuits, the analysis of the virtual short characteristic of operational amplifier achieves the dialectical unity of theory, simulation and practice, which further improves the theoretical knowledge of the virtual short characteristic of the operational amplifier, and lays a solid foundation for the analysis and application of operational amplifier. TGSPUT teaching model gives full play to the leading role of teachers in the teaching process and students' subjectivity. The blended integrated teaching method of measurement and control circuit course will play a prominent role in building the course into an 'Golden Course' with "high-order, innovation and challenges", and training advanced applied talents.

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